A DESCRIPTION OF A NEW
INSTRUMENT DENOMINATED THE
CELESTIAL OR VARIATION COMPASS

GRAYDON

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A

DESCRIPTION

OF A

LONDON NEW INSTRUMENT

DENOMINATED

THE CELESTIAL

OR

VARIATION COMPASS.

INVENTED BY

GEORGE GRAYDON,

CAPTAIN IN THE CORPS OF ROYAL ENGINEERS.

1826.

GENERAL DESCRIPTION AND USE
OF THE
CELESTIAL OR VARIATION COMPASS.

THE Celestial or Variation Compass, is adapted for finding the variation of the Compass at sight, at any time of the day, without the Horizon, and without Calculation—as also, for Surveying a Coast or Harbour, giving *true* bearings at sight, and for steering a vessel by the Sun *without the presence* of the Magnetic Needle, besides other important purposes.*

The construction of this instrument is simple, and the process of using it is very easy, requiring neither time nor capacity, and it is free from the difficulties which attend observations by Azimuth's and Amplitude's—the only means heretofore known of finding the variation of the Compass.

It is impracticable to calculate the variation of the Magnetic Compass in many cases, in consequence of the state of the atmosphere or the positions of the Heavenly bodies precluding the observation for an Amplitude or Azimuth. The Amplitude can only be taken at the rising or setting of the object, and the Azimuth can only be obtained with any degree of accuracy when the object is at a low altitude.

It will frequently happen, particularly in the Channels of the British Isles and along the Coasts of America, that the Horizon and several degrees above it, is so obscured for some days together, that these observations cannot be made although the Sky is sufficiently clear at a greater altitude. In these circumstances no variation can be calculated, except

* For a description of the principle upon which the Instrument is constructed, see the Appendix No. 1.

from the Tables or Charts of Navigation, which are becoming every day more and more uncertain—besides from the powerful effects of Terrestrial Magnetism, Meteoric influence, &c. the uncertain action,* and directive power, of the Magnetic Needle, frequently become worse than useless,† and the detection of such accidents must always depend upon Celestial observations, and these causes of error and uncertainty may remain operating imperceptibly for a considerable length of time, during which no observation to correct the variation can be made.

* The variation of the Magnetic Compass is different in different places at the same time, and different in the same place at different times.

† The following extract from Barlow's valuable work on Magnetic Attractions, shewing the uncertainty and *fallibility* of the Magnetic Compass without correction for the local attraction of the iron of the ship, is very applicable to many cases where correction for the variation cannot be obtained by Azimuth, either owing to an obscured Horizon, or the other causes above mentioned.

"Every reader, whether a nautical man or not, must be aware of the great amount of error and fatal consequences which might arise in a few hours to a vessel in the Channel in a dark and blowing night, having for its only guide a Compass subject to an error of 14 degrees in opposite directions at East and West, the very courses on which she would be endeavouring to steer, and who can say, how many of the mysterious wrecks which have taken place in the Channel, are to be attributed to this source of error, of which the most recent (that of the Thames Indiaman) is a serious example.

"This vessel, besides the usual materials, guns, &c. &c. had a cargo of more than 400 tons of iron and steel, and it may easily be imagined that such a cargo would produce an effect on the Compass at least equal to that of the Griper and Barracouta, and this alone would account for the otherwise unaaccountable circumstance, that, after having Beachy Head in sight at six o'clock in the evening, the vessel should have been wrecked upon the same spot at one or two o'clock in the morning, without the least apprehension of being at all near shore."

"Barlow on Magnetic Attractions," page 367.

DS

Description and Use of the Celestial Compass.—See Figure 1, Plate I.

Figure 1, Plate I, represents the instrument ready for use; it may be placed upon the deck, or any other part of the vessel, or upon a stand like the Azimuth Compass.

The following parts are those which require the particular attention of the observer—viz.

1. The circle C C upon which the Hours are marked.
2. The Arc of Latitude $g\ h$, and its Vernier h .
3. The Hour hand E and Lens O attached; as also the piece of ivory P adapted for receiving the Sun's concentrated rays.
4. The ring D D having the Cardinal points marked upon it.
5. The Magnetic card x , and Compass box K L;
 f the stop or trigger for stopping the Magnetic card.

Method of using the Instrument for finding the variation of the Compass at sight.—See Figure 1, Plate I.*

Elevate the arc $g\ h$ to the latitude of the place by turning the endless screw I. Set the hand E to the hour of the day, or *apparent*† time—Now move the box with the instrument until the Sun's rays (concentrated through the lens O) fall upon the centre of the ivory P.

In this position stop the Magnetic card x by pressing the trigger f .

The degree on the edge of the card corresponding with the stop or trigger, will indicate the variation of the Compass.

* Trials of the Celestial Compass were made on board His Majesty's Ships by order of the Lords Commissioners of the Admiralty, and have invariably succeeded. Copies of the reports of the Officers commanding, are given in the Appendix.

† Apparent time may be obtained from *mean* time by applying the Equation, or an altitude may be taken by the Celestial Compass for that purpose without the horizon. See page 8. The time need not be very accurately known—an error of even *four* minutes would make a difference of one degree only in the result.

In the figure, the stop or trigger is opposite to the N. E. point of the Magnetic card, or 45 degrees, and therefore the variation is four points *Westerly*.

Description and use of the Celestial Compass.—See Figure 1, Plate I.

The following is a particular description of the instrument and its relative parts—viz.

C C represents a circle of brass which is mounted upon pivots *d-d* passing through holes formed in a brass ring D D, so as to admit of moving therein, and the degree of angle at which it may have been placed, is determined by an arc of Latitude *g h*, (which is graduated with degrees) for which purpose a vernier *k* is affixed to the ring D D.

The circle C C is divided into 24 hours, or 360 degrees,* and having a brass bar A B fixed to it by screws. This bar receives the pivot upon which the hour hand E turns.

A vernier is attached to the extremity of the hand E for the purpose of reading off the hours and minutes† upon the circle C C. The hour hand E has also at its extremity a small pillar *o* projecting up from it, and carrying the lens O; and the extremity of the hand E is attached to a circular piece of brass *u u*, (which turns round with the hand E in a groove within the ring C C, for the purpose of giving steadiness to the pillar *o* and lens O, as they must then always be perpendicular to the plane of the ring C C in every position of the hand E.

P represents a small square of ivory which is mounted upon

* Each division on the ring C C is one degree or 4 minutes of time.—N. B. When the instrument is intended to be used *South* of the Equator, the horary circle C C has a double row of figures engraved upon it; the one numbered as usual from left to right—the other from right to left, according to the apparent motion of the Sun to an observer at the South side of the Equator; and of course this latter is the index which is then to be made use of.

† The vernier at the end of the hand E is divided so as to indicate *minutes*, each division being one minute of *time*.

a pillar p^* on the hand E, and the axis of this pillar, is in the centre of, and perpendicular to the bar A B, or to the plane of the circle C C.

The ring D D is attached to the upper part of the Compass box K L, and this box is suspended upon pivots at S-S, which move freely through holes formed in the gimbal ring which is suspended upon pivots at s-s, and turning in holes in the side of the box which contains the instrument.

The magnetic card x (graduated round its edge) is supported as usual by a pin projecting up from the bottom of the Compass box K L, and the point of this pin is in *the same* plane as that of the gimbal ring, or in a line corresponding with the axis of its pivots, to prevent the card from being disturbed by the motion of the vessel. It also coincides with the centre of motion of the whole instrument.

The ring D D has the Cardinal points marked upon it—the North point coinciding with the *true* meridian at the instant of taking the observation. By looking at the relative position of this point and the North point of the magnetic card, it will be seen how the parts concur to give the result, for the difference between them is the variation of the Compass;—if the North point of the magnetic card coincides in a line with the ring D D, there would then be no variation of the needle; if they differ, the angle of their difference is measured by that degree of the divided edge of the magnetic card which is seen to be opposite to the stop or trigger f .

By referring to the figure, the North East point of the magnetic card is there represented to be opposite to the stop or trigger f , or the North point of the ring D-D, and therefore the variation is four points Westerly.

When it is required to find the variation of the Compass by a fixed Star, the instrument is to be used as above described, except that, instead of the lens O, a slip of brass R carrying sights (see Figure 4,) is placed upon the pillar o for the pur-

*The pillars p and o are to be changed when the Sun's declination changes, viz. when the declination is North the lens O is to be placed upon the longest pillar; when the declination is South it is to be placed upon the shortest, and the square of ivory upon the longest pillar.

pose of directing the eye in a line towards the Star. Of course in this case the solar time must be converted into *sidereal**; and the hand E is to be set accordingly, as before directed.

Description and Use of the Celestial Compass adapted for taking true bearings without the presence of the Magnetic Needle.— See Figure 2, Plate I.

A ring F G carrying sights W *w* is to be placed upon the ring D D of the instrument represented by Figure 1.

After having set the arc *g h* to the latitude of the place, and the hour hand E to the apparent time, and having brought the Sun's concentrated rays to fall upon the ivory, the sights W-*w* are *then* to be directed to the object the bearing of which is required. By looking at the vernier attached to the under part of the sight W, the *true* bearing will be seen by reading off the divisions upon the ring D D.†

* Solar time is readily converted into sidereal time as follows—subtract the Sun's right ascension in time at noon from the Star's right ascension, the remainder will give the time of the Star's passing the meridian sufficiently near for practical purposes.

† In taking bearings with the Celestial Compass *South* of the Equator, it is evident that the cardinal points of the ring D D would be reversed for the South Pole would then be elevated. This change is readily effected by changing the North and South points of the ring D D, which are made moveable for that purpose. By removing a pin of the watch work, a reverse motion may be given to the hand E, for the purpose of steering at the *South* side of the Equator.

Description and Use of the Celestial Compass adapted for steering a true course, without the presence of the Magnetic Needle.— See Figure 1, Plate I. and Figure 3.

For this purpose watch work is attached to the instrument, by which the lens O is moved round once in 24 hours.* This is effected as follows :

By loosening the screws which are inside of the ring C C, the bar A B with the hand E and the ring *u u* may be removed, as also the card *x*, the pin and glass; and in place of them a dial plate having watch work carrying a hand and lens, is attached to the ring C C by screws in the same manner as the former.

The instrument is then to be placed upon a stand (see Figure 3,) having a pin *z* upon which the instrument may be turned round in any required position, the stand remaining fixed to the deck by screws *a-b-c* in the following manner, viz.—A line A B over or *parallel* to the keel line, is to be marked upon the deck, —the leg *a* of the stand is to be placed *upon* the line A B; each of the other legs of the stand *b* and *c* is to be fixed equally distant from the line A B, as represented in the figure.

Upon the leg *a* (which is to be towards the *head* of the vessel) is placed a pin or slip of brass *e*, to serve as an index by which to set the instrument according to the course required to be steered.

For example, see Figure 3.

Suppose it is required to steer a South course.

The instrument is to be turned round upon the pin *z* until the South point of the ring D D is brought opposite to the pin or index *e*. It is then to be clamped in that position by turning the clamp screw *d*.

The arc of latitude *g h* is to be set to the latitude and the hand E to the time as pointed out in the preceding directions. The helmsman has only to direct the vessel so that the Sun's

* A description of the principle upon which the Instrument is constructed is given in Appendix No. 1.

concentrated rays may remain upon the ivory. The vessel will then proceed in a true South course.

In like manner any other true course may be steered by the Celestial Compass, by setting it to the required course and keeping the concentrated rays upon the ivory as above directed.*

Although the method of steering a true course is not practicable when the Sun does *not* shine, that is no reason why it should not be resorted to when the Sun *does* shine—the presence of the Sun affords the means of steering a *true* course on an average at least *one third* of every voyage, whereby a considerable proportion of the risk and uncertainty of steering by the Magnetic Needle might be avoided.

Method of using the Instrument for taking an altitude without the Horizon.—See Figure 1, Plate I.

Set the arc g h to zero, by turning the endless screw I, by which the ring C C is brought perpendicular to the horizon.

Move the box with the Instrument and elevate the hand E until the Sun's rays (concentrated through the lens O) fall upon the centre of the ivory P.

The vernier at the extremity of the hand E will indicate the *altitude* in hours and minutes,† by taking a *mean* of several observations a near approximation to the altitude without the horizon may be attained.—See the Appendix, No. 2.

A description of another method of using the Celestial Compass for obtaining the apparent time at *sight* and without the horizon, is given in page 14.

* A trial of the Celestial Compass for steering a true course *without the presence of the Magnetic Needle*, was made in His Majesty's Ship Menai, and succeeded.—Copy of the report of the Officer commanding and of the Master, is given in the Appendix.

† The hours and minutes may be converted into degrees and minutes by reducing the hours into minutes, and dividing by 4.

N. B. The method of adjusting the Instrument is described in the Appendix No. 2.

Description and Use of the Celestial Compass adapted for Surveying a Coast or Harbour, without the presence of the Magnetic Needle.—See Figures 1, 2, and 3.

A description of the Celestial Compass adapted for taking true bearings, having been already given, as also for steering a true course without the presence of the magnetic needle, it is obvious, that, when both these properties of the instrument are combined, it is adapted for surveying a Coast or Harbour by the true meridian.

For this purpose it is only necessary to place the ring F G carrying sights (see Figure 2,) upon the ring D D. The instrument is then to be used in like manner as has been described in taking true bearings and in steering a true course. For example see Figures 1, 2, and 3.

Considering the base line as the given course to be steered and having set the instrument accordingly, placing the vessel in such a position that the Sun's concentrated rays may fall upon the ivory, the bearings of the several head-lands and other conspicuous parts of the coast, are to be taken by moving the sights as before directed. Having thus taken the angles at one extremity* of the base line, the vessel is then to be steered in the given course, (which is in fact sailing along the base line) the length of which may be measured either by the log or by the intersection of points on the land previously determined, or by the interval between the flash and report of a gun†; the bearings of the same objects may also be taken at the other extremity of the base line, by which means the survey may be plotted upon paper according to the usual mode of laying down surveys, except that the plan is formed according to the *true* instead of the magnetic meridian, which is always variable from local attraction or terrestrial magnetism.

* The angles or bearings need only be taken at every *other* station, as in surveying with the Theodolite.

† See Appendix No. 3—in which is given detailed directions for Maritime Surveying.

By means of the Celestial Compass, Professor BARLOW's plate may readily be attached; as the *true* bearing may be obtained at once.

This mode of surveying a coast or harbour, is not only *true*, but is extremely simple and expeditious.

Trials of the Celestial Compass in several of His Majesty's vessels were ordered by the Lords Commissioners of the Admiralty, on the recommendation of the Board of Longitude; the successful results of these numerous experiments (as shewn by the reports* of the Officers commanding) demonstrate its practical merits and importance; and the instrument has fully accomplished the purposes for which the trials were made.

* Copies of the Reports are given in Appendix.

Description of the Celestial Compass, adapted for finding the Latitude and apparent time by inspection, without the horizon. See Figures 1 and 6.

The Celestial Compass adapted for the above purposes is intended as a substitute for the Sextant, when that instrument cannot be used, owing to an obscured horizon, which is generally the case on making land, when Celestial observations become most important—or in cases when the positions of the heavenly bodies are unfavorable for computing either the time or the latitude, by altitudes.

In these critical situations the Celestial Compass may be used independently of the horizon, and at any time when the Sun is visible whether it be near the meridian or not.

A Dial plate A B (Figure 6) similar to that described in page 9, is to be placed upon the ring C C, (Figure 1,) and having an hour or index hand E which is formed to a vernier at one of its extremities to read off the degrees upon the Dial plate; *p* represents a pillar on the hand E, and the axis of which is in the centre of and perpendicular to the Dial plate; upon the pillar *p* is placed an arm carrying the arc of declination S S, and capable of being elevated or depressed upon the pivot *s-s* in the fork at the upper part of the pillar *p*. This arm has at one of its extremities a piece of brass *q*, having a dot in its centre of platina, adapted for receiving the Sun's concentrated rays through the lens O.

The arc S S is graduated, and it is provided with a vernier *r* (which is attached to the under part of the pillar *p*) and is adapted for indicating any degree of inclination of the arm relatively with the plane of the Dial plate A B. For example, in the figure the vernier indicates that the arm is inclined at an angle of 10 degrees with the Dial plate A B, which represents the plane of the Equator, for when the arc of latitude *g h* (see Figure 1) is elevated to the latitude of the place, the plane of the circle C C or of the Dial plate, will be in a position parallel to the Earth's Equator, and therefore the relative position of the arm will represent the Sun's declination.*

* A further description is given in the Appendix No. 1.

For example, see Figures 1 and 6.

Having placed the Dial plate described in Figure 6, upon the ring C C, set the arc S S (Figure 6) to the Sun's declination, the hand E to the apparent time.

Elevate the arc of latitude g h (Figure 1) by turning the screw I until the Sun's rays concentrated through the lens O, are brought to coincide with the point or dot in the centre of the piece of brass q. The latitude of the place will be shewn by the vernier k.

Method of using the Instrument for finding the apparent time without the horizon—the latitude being given, nearly.—See Figures 1 and 6, as before.

Having placed the dial plate shewn in Figure 6, upon the ring C C, Figure 1, and having set the arc S S to the Sun's declination, elevate the arc g h to the latitude—move the hand E until the Sun's rays, concentrated through the lens O, are brought to coincide with the dot upon the piece of brass q.

The vernier at the extremity of the hand E will then indicate the apparent time.

APPENDIX.

No. I.

THE following is the principle upon which the Celestial Compass is constructed, viz.:

The apparent motion of the Sun being caused by the uniform rotation of the Earth upon its axis from West to East, once in twenty-four hours, it will appear evident, that, if an arm be moved with an equable motion in a contrary direction to the apparent motion of the Sun, and having its axis of motion in a position parallel to the Earth's axis,* the arm would keep pace with the apparent motion of the Sun, while it describes its horary angle; if, therefore, the time be given, and the arm be set to that time, and be directed towards the Sun, the noon hour line would then be situated in the true meridian.

For example, see Figures 4 and 5, Plate III.

Let O P represent the arm, A F G, a circle described about its axis P, and divided into twenty-four equal parts or hours. When the arm O P is set to the apparent time, suppose three hours, or 45° from the meridian, the instrument is then to be turned so as to bring the arm in a line between the axis P and the Sun S. The arm will then, by its motion, continue to perform the same horary angle as the Sun appears to describe, and A P, being the noon hour line, will therefore always indicate the true meridian.

In like maner, the true meridian may be indicated by means of a Star, by calculating its distance from the plane of the meridian, or its horary angle at the time of observation, and setting the arm accordingly.

* The Earth, seen from the Sun, would appear but as a point, and the centre of motion of the arm may therefore be considered as coinciding with that of the Earth.

As the relative position of the Sun or a Star, with regard to the plane of the meridian, may be determined as above, its declination may also be determined as follows:—See Figure 5, Plate III.

Let Figure 5, Plate III. represent the exact position of the sphere, having its axis PP elevated to the latitude of the place, and the arm Oo set according to the apparent time, suppose three hours, or 45° from the meridian, and directed to the Sun S .

The meridian distance of the Sun S , or the angular distance between the plane of the arm Oo in that position, and the noon hour line AP , will be equal to forty-five degrees, because the instrument, being an exact representation of the position of the Earth, having the axis P parallel to the pole, and the noon hour line AP parallel to the plane of the meridian, the horary angle is the measure of the meridian distance of the object S . In like manner, a line EQ , which is perpendicular to the axis PP , or to the Pole, will be parallel to the plane of the Equator, with which it will continue to maintain the same relative position during the motion of the arm Oo round its axis PP .

As the arm Oso is an arc of a circle of which P is the centre, therefore, when the object has no declination, it will appear in the direction EQ , or the line SOP will coincide with the line EPQ . But when the object S declines from the Equinoctial, the measure of its declination will be shewn by the part of the arc Oso which is above EQ , of which arc the sight at P is the centre. The curve Oso having a sight at O , is moveable within the fixed part of the arm o , and may be raised or lowered so as to bring the sight at O in a line between the object S and the other sight at P .

The fixed part of the arm at o is graduated from each side of o ; the vernier upon the moveable curve at o will indicate the amount of the angle of elevation or depression of the sight of O , above or below EQ , which angle is equal to the apparent declination of the object S at the time of observation. For example, in the Figure, the sight O is ten degrees above the

Equinoctial line $E Q$, because the vernier placed upon the moveable curve is ten degrees higher than o in the index of the fixed part of the arm. On the contrary, if the sight O were below the Equinoctial line $E Q$, the vernier would be depressed in the same proportion below o on the index. The declination will of course be shewn, not only for noon and midnight, but for any intermediate time, and therefore the quantity of increase or decrease for any given time will also be shewn.—See Figure III. Plate I. A further example is given by Figure III. Plate I., which represents the oblique position of the sphere of which M is the centre, $E Q$ the Equator, $n m$ a parallel of declination of the object S , $P S P$ a circle of declination at the given time, suppose three hours, or forty-five degrees from the meridian. The arc $S d$, equal to the arc $E n$, is also the measure of the angle $d M S$ or $E M n$, the angle formed by the plane of the Equator and $M n$, or equal to that formed by the line $E Q$ of the instrument and the ray $O P$ of the object S .

APPENDIX.—No. II.

Construction and adjustments of the instrument, see Figure 1, Plate I.

This instrument is so constructed and balanced, that, it will always retain its horizontal position whatever may be the degree of inclination of the ring C C to the horizon according to the latitude of the place, because the centre of gravity of the ring C C is made to coincide* with the axis of its motion upon the pivots *d-d*, and when once the instrument shall have been properly balanced upon the gimbals, by means of a weight attached to the bottom of the Compass box K L, it will afterwards retain its horizontal position in every latitude.

To adjust the vernier k of the arc g h.

Let the instrument be taken out of the gimbals ring and placed upon a table or other level surface. Set the hand E to 12 o'clock; and having placed a spirit level upon the hand E, move the ring C C upon its pivots until the hand E is brought horizontal—keeping the ring C C and the hand E in this position, move the vernier K up or down until its zero is brought to coincide with 90 degrees on the arc g h.

To adjust the vernier of the hand E.

Having placed a candle or lamp at some distance from the instrument, elevate the arc g h to Zero, and move the hand E until the rays of the candle, concentrated through the lens, fall upon the ivory P, note the altitude indicated by the vernier at the end of the hand E; Now move the instrument in Azimuth half round, and at the *other side* of the ring C C obtain the altitude of the lens O in like manner as before. If these two altitudes agree, there is no index error; if they differ, half their difference is

* This adjustment may be effected by screwing up or down a small weight which is placed upon the pivot below the pillar p.

the index error, which may be entirely corrected by moving the vernier accordingly, without moving the hand itself.

When the instrument shall have been accurately adjusted as above described, it will appear evident that *altitudes* may be taken by it without the horizon.

To adjust the whole Instrument.

Having placed a spirit level in the bottom of the Compass box K L, it is to be brought horizontal by unscrewing one of the gimbal screws S, and screwing the other.

The spirit level is then to be placed at right angles with its former position, and the instrument must be brought horizontal in that direction also—the glass is then to be placed upon the Compass box.

The above are the only requisite adjustments, and which may be made by the observer himself whenever the instrument requires it, but such is the simplicity of its construction, depending upon the laws of *gravity*, that it is not liable to get out of order, and it is therefore well adapted to the purposes for which it is intended, in any part of the world.

N. B. A Patent has been obtained for the CELESTIAL COMPASS, and the instrument may be procured at Messrs. WARRE, BROTHERS & CO. No. 13, Austen Friars, London.

APPENDIX.—No. III.

The following directions for Maritime Surveying, are extracted from ADAMS' Geometrical and Geographical Essays:

MARITIME SURVEYING.

It was not my intention at first to say any thing concerning maritime surveying, as that subject had been very well digested by Mr. MURDOCH MACKENZIE, whose treatise on *Maritime Surveying* ought to be in every person's hands who is engaged in this branch of surveying, a branch which has been hitherto too much neglected. A few general principles only can be laid down in this work; these, however, it is presumed, will be found sufficient for most purposes; when the practice is seen to be easy, and the knowledge thereof readily attained, it is to be hoped, that it will constitute a part of every seaman's education, and the more so, as it is a subject in which the safety of shipping and sailors is very much concerned.

1. Make a rough sketch of the coast or harbour, and mark every point of land, or particular variation of the coast, with some letter of the alphabet; either walk or sail round the coast, and fix a staff with a white rag at the top at each of the places marked with the letters of the alphabet. If there be a tree, house, white cliff, or other remarkable object at any of these places, it may serve instead of a station staff.*

2. Choose some level spot of ground upon which a right line, called a *fundamental base*, may be measured either by a chain, a measuring pole, or a piece of log-line marked into feet; generally speaking, the longer this line is, the better; its situation must be such, that the whole, or most part of the station-staves may be seen from both ends thereof; and its length and direction must, if possible, be such, that the bearing of any station-staff, taken from one of its ends, may differ at least ten degrees from the bearing of the same staff taken from the other end; station-staves must be set at each end of the fundamental base.

* See Nicholson's Navigator's Assistant.

If a convenient right line cannot be had, two lines and the interjacent angles may be measured, and the distance of their extremes found by construction, may be taken as the fundamental base.

If the sand measured has a sensible and gradual declivity, as from high-water mark to low-water, then the length measured may be reduced to the horizontal distance, which is the proper distance, by making the perpendicular rise of the tide one side of a right-angled triangle; the distance measured along the sand, the hypotenuse; and from thence finding the other side trigonometrically, or by protraction, on paper; which will be the true length of the base line. If the plane measured be on the dry land, and there is a sensible declivity there, the height of the descent must be taken by a spirit-level, or by a quadrant, and that made the perpendicular side of the triangle.

If in a bay one straight line of a sufficient length cannot be measured, let two or three lines, forming angles with each other, like the sides of a polygon, be measured on the sand along the circuit of the bay; these angles carefully taken with a theodolite, and exactly protracted and calculated, will give the straight distance between the two farthest extremities of the first and last line.

3. Find the bearing of the fundamental base by the compasses, as accurately as possible, with Hadley's quadrant, or any other instrument equally exact; take the angles formed at one end of the base, between the base line and lines drawn to each of the station-staves; take likewise the angles formed between the base line and lines drawn to every remarkable object near the shore, as houses, trees, windmills, churches, &c. which may be supposed useful as pilot marks; from the other end of the base, take the angles formed between the base and lines drawn to every one of the station staves and objects; if any angle be greater than the arc of the quadrant, measure it at twice, by taking the angular distance of some intermediate object from each extreme object; enter all these angles in a book as they are taken.

4. Draw the fundamental base upon paper from a scale of equal parts, and from its ends respectively draw unlimited lines, forming with it the angles taken in the survey, and mark the extreme of each line with the letter of the station to which its angle corresponds. The intersection of every two lines, whose extremes are marked with the same letter, will denote the situation of the station or object to which, in the rough draught, that letter belongs; through, or near all the points of intersection which represent station-staves draw a waving line with a pencil to represent the coast.

5. At low water sail about the harbour, and take the soundings, observing whether the ground be rocky, sandy, shelly, &c. These soundings may be entered by small numeral figures in the chart, by taking at the same time the bearings of two remarkable objects; in this excursion, be particular in examining the ground off points of land which project out into the sea, or where the water is remarkably smooth, without a visible cause, or in the vicinity of small island, &c. observe the set and velocity of the tide of flood, by heaving the log while at anchor, and denote the same in the chart by small darts. The time of high water is denoted by Roman numeral letters; rocks are denoted by small crosses; sands, by dotted shading, the figures upon which usually shew the depth at low water in feet; good anchoring places are marked by a small anchor. Upon coming near the shore, care must be taken to examine and correct the outline of the chart, by observing the inflections, creeks, &c. more minutely.

6. In a small sailing vessel go out to sea, and take drawings of the appearance of the land, with its bearings; sail into the harbour, observe the appearance of its entrance, and particularly whether there be any false resemblance of an entrance by which ships may be deceived into danger; remark the signs of the objects, by attending to which, the harbour may be entered in safety; more especially where it can be done, let the ship steer to the anchoring place, keeping two remarkable objects in one, or on a line.

7. Coasts are shaded off on the land side; houses, churches, trees, &c. on shore, are drawn small in their proper figures; in a proper place of the chart, draw a mariner's compass, to denote the situation of the rhumbs, &c.; and on one side of the flower-de-luce, draw a faint half flower-de-luce at the point of north by compass; draw also a divided scale of miles, or leagues, which must be taken from the same original scale as the fundamental base.

Charts or plans may be neatly drawn with Indian ink, or the pen and common ink, and are as useful as any others, but they are frequently done in water colours; for which purpose the beginner will derive more advantage from viewing a proper drawing, or from overlooking a proficient at work, than from a multitude of written instructions.

An example to illustrate the foregoing precepts.—Let A B C D E F G H, *plate 4*, represent a coast to be surveyed, and I K L, an adjacent island; it is required to make an accurate chart of the same.

To make the actual observation on shore.—By sailing or walking along the shore, a rough sketch is made, and station staves set up at the points of land, A, B, C, D, E, F, G, H, and also at I, K, L, on the island, precept 1. During this operation, it is observed, that no proper place offers itself at which a fundamental base can be drawn, so as to command at once a view of all the stations; it will therefore be necessary to survey the coast in two separate parts, by making use of two base lines; if the coast had been more extended, or irregular, a greater number of base lines might have been necessary. Between the points B and C, the ground is level, and a considerable number of the southernmost points may be seen from both points, conformable to precept 2; make B C, therefore, the first fundamental base, its length by admeasurement is found to be 812 fathoms, and its bearing by compass from B to C, is N. $11^{\circ} 14'$ E. from each end of this base, measure with HADLEY's quadrant or sextant the angles formed between it, and lines drawn to each station in sight, precept 3, enter, or, tabulate them as follows:

First fundamental base B C=812 fathoms, bearing of C from B, N. $11^{\circ} 14'$ E.

Angle	A B C =	135 07	Angle	A C B =	22 54
	L B C =	85 00		L C B =	71 02
	K B C =	56 28		K C B =	91 40
	E B C =	43 32		E C B =	113 50
	D B C =	13 30		D C B =	145 20

After having made these observations, it will be requisite to proceed to the northern part of the coast; in all cases where a coast is surveyed in separate parts, it is best to measure a new fundamental base for each part, when it can be conveniently done; a line from the station E drawn towards F, is well adapted to our purpose; let E P, therefore be the second base line, its length by admeasurement is found to be 778 fathoms, and its bearing by compass from E to F, N. $38^{\circ} 20'$ E. Measure the angles formed by lines drawn from each end of this base, as before directed, and tabulate them as follows:

Second fundamental base E P = 778 fathoms, bearing of P, from E. N. $38^{\circ} 20'$ E.

Angle	H E P =	88 30	Angle	H P E =	73 00
	I E P =	71 32		I P E =	28 54
	G E P =	43 59		G P E =	111 00
	F E P =	27 51		F P E =	127 18

It is sufficiently apparent, that the connexion between the two parts of this survey is preserved by the second fundamental base being drawn from the point E, whose situation was before determined by observations from the first base line; if this particular position of the second base had not been convenient, and it had been taken at a distance from every point determined in situation from the first base, the connexion would have required an observation of the bearing of one of the said points from each end of the second base: thus, suppose the line I P to be the second base line, instead of E P; the position of I P with respect to the given point E, may be known by taking the bearings of E, from I and P.

All the observations which are required to be made on shore, being now completed, it will be advisable to construct the chart before we proceed to the other observations on the water, for, by this method, an opportunity is offered of drawing the waving line of the coast with more correctness than could otherwise be obtained.

GEOMETRICAL CONSTRUCTION, *plate 4.*

On the point B as a centre, describe the circle *n e s w*, the diameters *n s* and *w e* being at right angles to each other, and representing the meridian and parallel; from *n* set off the arc *n N*, equal to the quantity of the variation of the compass; draw the diameter *N S*, and diameter *W E* at right angles to the same; these lines will represent the magnetic meridian, and its parallel of latitude.

From the centre B, draw the first base line *B C* = 812 fathoms, N. 11° 14' E. by compass; from one extremity B, draw the unlimited lines *B a B I*, *B k*, *B e B d*, forming, respectively with the base, the angles observed from thence; from the other extremity C, draw the unlimited lines *C a*, *C I*, *C k*, *C e*, *C d*, forming, respectively with the base, the angles observed from thence; the intersections of lines terminated by the same letter, will give the stations A, L, K, E, D, precept 4.

Draw the line *B Q*, N. 38° 20' E. by compass, and from E, draw *E P* = 778 fathoms in the same direction or parallel to it, *E P* will be the second base line; from one extremity E, draw the unlimited lines *E h*, *E i*, *E g*, *E f*, forming, respectively with the base, the angles observed from thence; from the other extremity P, draw the unlimited lines *P h*, *P i*, *P g*, *P f*; the intersection of lines terminated by the same letter will give the stations H, I, G, H, F, precept 4.

Near the points A, B, C, D, E, F, G, H, draw a waving or irregular line to represent the coast; draw also by the help of the points I, K, L, a line to represent the coast of the Island.

The chart being thus far delineated, it will be proper to make the observations which are required on the water.

TO MAKE THE ACTUAL OBSERVATIONS ON THE WATER.

Precept 5, sufficiently explains the business to which it is necessary to attend on the water: nothing more, therefore, need be added here, except an elucidation of the method, by the place at which any observation is made, may be found on the chart; the place of an observer may be determined by the bearings of two known objects; the intelligent practitioner will find reasons for occasionally preferring each of these methods; but, as the distance in the second method is known only by estimation, we have given the preference to the first, in the present example; all the soundings, &c. are supposed to be laid down by these methods, but, to prevent confusion and prolixity, the lines of bearing are drawn only from the points M, N, and O.

From the southern extremity M, of the reef of rocks, which runs off the point L, the bearing of the stations C and B are taken by the compass, as follows, viz. C. N. 62° E. and B, N 85° E.

On the chart therefore, from C, parallel to the rhumb B R, draw the opposite rhumb C m, S. 62° W. and from B, draw the opposite rhumb B m, S. 85° W. their intersection M, will be the extremity of the reef of rocks.

Again, from the sand head N, the bearings of the stations L and K are taken by the compass, as follows, viz. L, N. 17° W. and K, N. 5° E.

On the chart draw the rhumb B n, N. 17° W. and from L. parallel to the same, draw the opposite rhumb L n; draw likewise the rhumb B T, N. 5° E. and from K, parallel to the same, draw the opposite rhumb K n; the intersection of these two last lines will be the sand head, and the situation of the point of land O, which lies so that it cannot be seen from either of these base lines, is determined in like manner from the bearings of L and K, though in practice it may have been more convenient to settle its place from a single bearing and distance of the station A.

The position of the compass is given from that of the circle N E S W, made use of in the construction, and the scale of geographical miles is found from the consideration, that 1021 fathoms make one geographical mile; take therefore 1021 from the same scale of equal parts, as was used in laying down the fundamental basis, and it will give one primary division for the intended scale of miles.

To measure a straight line on the surface of the sea.—First, prepare a measuring line of strong chord, two or three hundred yards in length, with small pieces of cork of equal thickness made fast to it at small distances, all along, like a fishing net, so that it may float straight on the surface of the water: if the line has been well stretched, or much used before, it is the better; also prepare two ropes somewhat longer than the greatest depth of the water to be measured, with a pig of lead or iron ballast, which we call an anchor, 50 or 60 pounds weight, tied by the middle to one end of each rope, that when it is at the bottom it may be able to anchor a boat, and bear to be stretched straight without shifting the place of the anchor. Let the measuring line be thoroughly wet immediately before you begin to use it, and then stretched on the water close by the shore, and its length measured there with a pole. Then, in the direction intended to be measured, take two remarkable sharp objects on the land in a line, one near the shore, the other as far up in the country as you can: if such are not to be had, place buoys on the water at proper distances in that direction.

2. Take the objects, or buoys, in a line, and holding one end of the measuring line fast on the shore, carry out the other in a boat, in that direction, till it is stretched straight at its full length by one man in the boat, and exactly at the end of the line let another man drop the anchor, which will mark one length of it. There keep the boat, and the end of the measuring line, close to the anchor rope, drawn tight up and down, till another boat takes in the other end which was on the shore, and rows farther on, and lays it straight in the direction of the land marks, or buoys, and there drops another anchor, which will mark the second length of the measuring line. Go on thus

till the whole proposed distance is measured ; and immediately after let the measuring line be again measured with a pole on the water near the shore, as at first, and if the lengths differ, take the mean between them for the true length. It is obvious, that to measure with any exactness this way, the sea must not only be smooth, but void of a swell, and of all stream of tide ; either of which will hinder the line from lying straight. This method of measuring a straight line may be convenient on some occasions ; and if care is taken to keep the anchor rope right up and down when the measuring line is applied to it, will be found sufficiently exact for many purposes, but not for a fundamental base line from which other distances are to be deduced.

There is another way of measuring a straight line, mechanically, on the sea, which is so well known to seamen, that it is needless to describe it particularly here : and that is, by heaving the log over a ship's stern while she is under sail, and observing how many knots of the log line run out in half a minute ; for the line is so divided that the ship will run, or is supposed to run, so many miles in an hour, in a straight course ; and twice as much in two hours, and so on. But this conclusion is founded on three suppositions, neither of which is certain, viz. that the log remains in the same place during the whole half minute that the line is running out from the ship's stern ; that the ship continues to sail with the same velocity, and also in the same direction, during an hour, or two, that she did during the half minute ; the contrary of which is more likely in most cases. For the log line may shrink, or stretch, while it is running out ; or may drag after the vessel by the weight of the line, or by not running easily and readily off the reel ; the swell of the sea may alter the place of the log ; and currents, or streams of tide, stronger or weaker below the surface than on it, an unsteady helm, lee-way, and varying winds, may change the direction, or celerity of the ship's motion ; for neither of which can any certain allowance be made. This way, therefore, of measuring a straight line, or distance, is not to be depended on as exact ; but is mentioned here, because rocks, shoals, or islands, sometimes lie so far from the coast, that there is no other way of forming any notion of their distance. If any such distance is

to be measured after this manner, let the log-line be thoroughly wet when it is measured; let the length between each knot be 51 feet, which is the 120th part of a geometrical mile, as half a minute is 1-120th part of an hour. Choose neap-tide, as much slack water as can be got, and a moderate breeze of following wind; let the line be run off the reel so as never to be stretched quite straight; and if the half minute is measured by a watch that shews seconds, rather than by a glass, it will generally be more exact. Perhaps one second should be allowed for the loss of time in calling out at the beginning, and stopping it at the end of the time; except the person who holds the watch can contrive to observe the going out of the red rag at the beginning, and also to stop the line himself at the end of the time; which does not seem a difficult matter.

To find the distance of two places by the flash and report of a gun.—Sound moves 1142 English feet in one second of time, or 6120 feet, which makes a geographical mile, in $5\frac{1}{3}$ " nearly; therefore, let a gun be fired at one place at an appointed time, and observe the time that elapses between the flash and report, and so many seconds as you observe, so many times 1142 feet are you distant from the place; the operation should be repeated two or three times for greater certainty. The distance to be measured this way should never be less than two miles, on account of errors that may arise in taking the time.

Fig. 1.

Fig. 2.

Fig. 3.

*A Celestial Compass for taking Bearings without Magnetic Aid.
Furnished to Captⁿ. Franklin. R.N. for the use of the Land Polar Expedition in the year 1825.*

The Supreme Court of the State of New York

Fig. 1.

*A Portable Compass for taking Bearings without Magnetic Steel.
Furnished to Captain Franklin, U.S.N. for the use of the Land Polar Expedition in the year 1825.*

Pl 2.

Ordr 1824.

Joseph Farey, de

Edm^d Turrell, sculp.

A Compass for Steering Ships without Magnetic Aid.

Pl. 2.

Ordered by the Lords of the Admiralty; and sent out with H. M. S. Hecla; on the Polar Expedition in the year 1824.